PERFORMANCE OF THE LTC1650 16-BIT DIGITAL-TO-ANALOG CONVERTER AT CRYOGENIC TEMPERATURES

Test Report

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Background

The Linear Technology LTC1650 is a 16-bit digital-to-analog converter (DAC) that is capable of unipolar or bipolar output swing. It features a digital three-wire cascadable serial input interface and has excellent accuracy over its full operating temperature range with very low power dissipation. The device rail-to-rail buffered output can source or sink a current of 5 mA over the entire specified operating range [1].

Test Setup

Three industrial-grade (AIN) devices of the LTC1650 DAC were evaluated from room temperature to -190 °C in a liquid nitrogen cooled chamber. Test were performed at temperatures of 25, -25, -50, -100, -150, -170, -180 and -190 °C. At each test temperature, the device was allowed to soak for 10 minutes before measurements were made.

The devices were evaluated in terms of their analog converted output characteristics and the internal reference resistance. The device output was configured for unipolar operation with no external load connected. The applied voltages to the reference inputs (REFHI) and (REFLO) pins were 4.0V and 0V, respectively. This allowed an output voltage swing of 0V to 4.0V. The serial digital input, which included the input to the clock (CLK), the chip select/data load ($\overline{CS}$/LD), and the 16-bit data word (D_{IN}), was supplied via a pattern generator that was programmed to produce a specific output voltage.

Thermal cycling was also performed on the three devices in the temperature range of +85 °C to -190 °C for a total of ten cycles. A temperature rate of change of 15 °C /min was used. During each cycle, the device under test was allowed to soak for 20 minutes at the extreme temperatures, i.e. +85 °C and -190 °C.

Results and Discussion

The converted analog output of device 1 for various digital input levels is shown at different test temperatures in Table I. It can be clearly seen that the analog output level tracks its digital input counterpart quite well throughout the test temperature range of +25 °C to -190 °C. The waveform of this output recorded at the extreme temperatures of 25 °C and -190 °C is depicted in Figure 1a and 1b, respectively. The only apparent changes resulting from the low temperature exposure are the appearance of a few spikes at the transition times and a slight increase in the output settling time. These insignificant changes seem to occur only at temperatures below -170 °C.

The full-scale analog output voltage, which corresponds to a full-scale digital input of 3.97V, is shown as a function of temperature in Figure 2. The values of this output ranged between 3.978V and 3.992V within the span of the test temperatures. This translates into a gain error, excluding the required adjustment of the offset error, of 8 to 22 mV. Although this gain error far exceeds the manufacturer's specified limit, it is believed that instrumentation inaccuracies and parasitic associated with circuit layout, such as long lead wire, might have contributed to this outcome. These factors might have also contributed to the appearance of the few spikes and the increase in settling time, as discussed previously. Nonetheless, the device seemed to produce a consistent output regardless of the test temperature.

The other parameter of the device that was investigated in this work was the internal reference resistance. This property seemed to exhibit a gradual, but very slight, decrease with decrease in temperature as shown in Figure 3. For example, this decrease amounted to only about 3.7% at the lowest temperature of -190 °C.

Similar to device 1, the other two devices displayed comparable behavior in their investigated properties with temperature. The results pertaining to device 2 in terms of its converted analog output, output waveform, and internal reference resistance are shown in Table II and Figures 4-6. Likewise, those for device 3 are shown in Table III and Figures 7-9.

The three devices were also thermal cycled in the temperature range of +85 °C to -190 °C for a total of ten cycles. During each cycle, the device under test was allowed to soak for 20 minutes at the extreme temperatures, i.e. +85 °C and -190 °C. The pre-thermal cycling output waveform for device 1 is shown in Figure 10a and 10b at +85 °C and -190 °C, respectively. Those obtained after the fifth and the tenth final cycle are shown in Figures 11 and 12, respectively. It can be clearly seen that thermal cycling did not have any significant effect on the performance of the device as the output voltage waveform was almost an exact replica under the three conditions, as depicted in Figures 10-12.

Similar to device 1, the other two devices did not undergo any changes in their output characteristics with thermal cycling. Although the data pertaining to device 2 and 3 is not presented graphically, their output waveforms resembled that of device 1.

Conclusion

Three devices of the industrial-grade LTC1650AIN 16-bit digital-to-analog converter were evaluated in terms of their output characteristics in the temperature range of 25 °C to -190 °C. These devices, which are rated for -40 °C to 85 °C operation, were also investigated under thermal cycling between +85 °C and -190 °C. The results obtained in this limited investigation indicate that all devices exhibited good operational behavior in their output characteristics with temperature. Only minor changes, which included a reduction in the output settling time and the appearance of a few spikes at the transition times, seemed to occur at very low temperatures. Further testing under long term temperature exposure is, however, needed to establish operational performance and reliability of these devices and to determine their suitability for low temperature applications.

References

1. LTC1650 Low Glitch 16-Bit Voltage Output DAC Data Sheet, Linear Technology.

Acknowledgments

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Table I. Analog converted outputs for device 1 as a function of temperature.

	Digital Input Voltage (V)							
	3.97	**0**	**0.662**	**1.323**	**2.432**	**2.779**	**3.474**	**1.615**
Temp (°C)	**Analog Output Voltage (V)**							
25	3.978	-0.053	0.622	1.298	2.427	2.782	3.485	1.593
-25	3.983	-0.044	0.637	1.31	2.437	2.792	3.495	1.61
-50	3.991	-0.039	0.639	1.313	2.439	2.791	3.493	1.604
-100	3.992	-0.04	0.638	1.316	2.442	2.79	3.494	1.606
-150	3.986	-0.046	0.626	1.303	2.431	2.781	3.486	1.592
-170	3.983	-0.048	0.624	1.298	2.426	2.779	3.478	1.597
-180	3.983	-0.047	0.627	1.3	2.429	2.78	3.48	1.591
-190	3.985	-0.06	0.624	1.3	2.425	2.78	3.48	1.59
25	3.983	-0.053	0.623	1.302	2.433	2.782	3.484	1.591

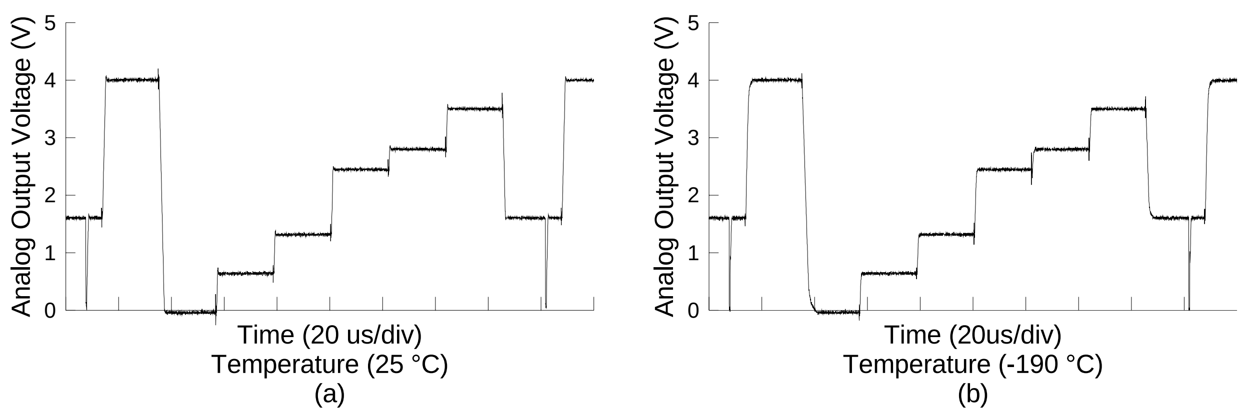

Figure 1. Output voltage waveforms for device 1 at 25°C and -190°C.

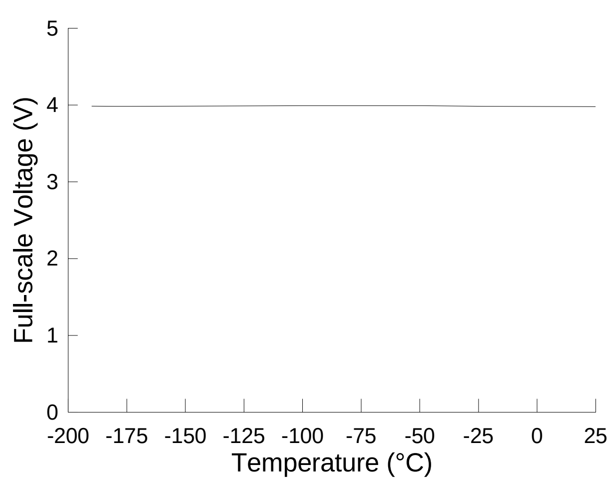

Figure 2. Device 1 full-scale voltage versus temperature.

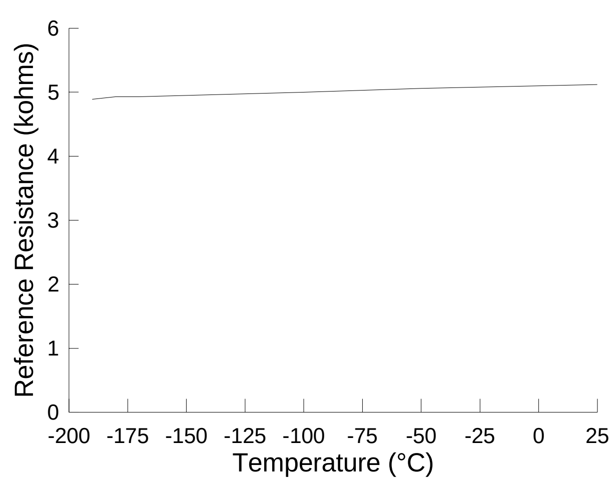

Figure 3. Device 1 reference resistance versus temperature.

Table II. Analog converted outputs for device 2 as a function of temperature.

	Digital Input Voltage (V)							
	4	**0**	**0.667**	**1.333**	**2.45**	**2.8**	**3.5**	**1.627**
Temp (°C)	**Analog Output Voltage (V)**							
25	4.02	-0.032	0.651	1.33	2.461	2.81	3.518	1.619
-25	4.01	-0.03	0.653	1.33	2.461	2.814	3.516	1.619
-50	4.014	-0.027	0.654	1.331	2.459	2.81	3.51	1.618
-100	4.013	-0.028	0.651	1.33	2.457	2.81	3.513	1.618
-150	4.008	-0.03	0.654	1.329	2.457	2.81	3.512	1.618
-170	4.019	-0.029	0.654	1.33	2.463	2.814	3.518	1.619
-180	4.01	-0.031	0.652	1.331	2.46	2.811	3.513	1.619
-190	4.013	-0.032	0.65	1.33	2.461	2.813	3.516	1.619
25	4.011	-0.031	0.649	1.328	2.46	2.813	3.515	1.618

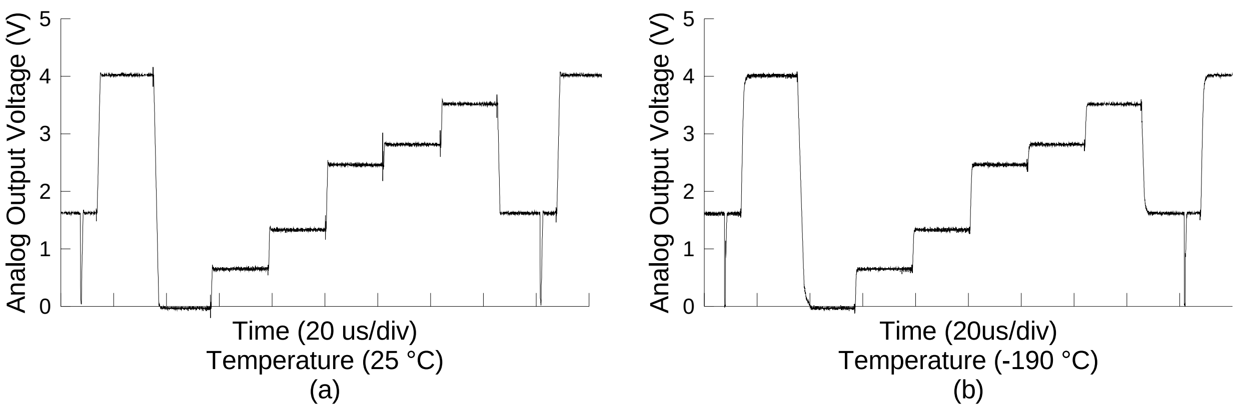

Figure 4. Output voltage waveforms for device 2 at 25°C and -190°C.

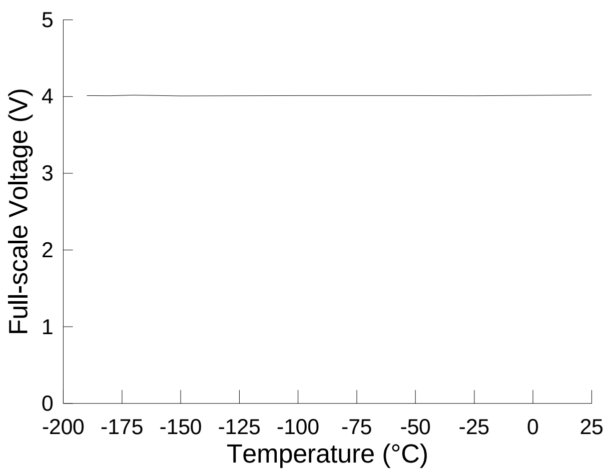

Figure 5. Device 2 full-scale voltage versus temperature.

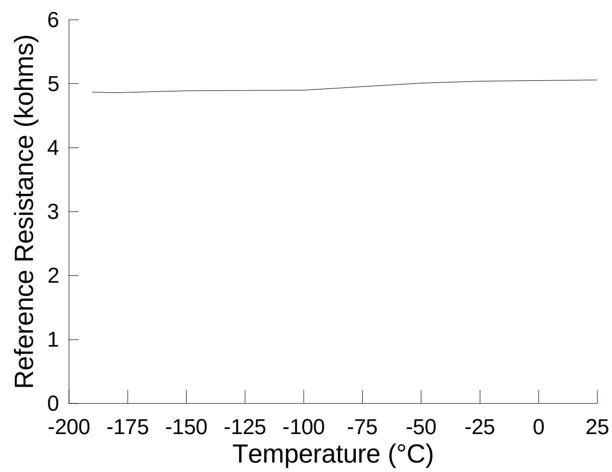

Figure 6. Device 2 reference resistance versus temperature.

Table III. Analog converted outputs for device 3 as a function of temperature.

	Digital Input Voltage (V)							
	4	**0**	**0.667**	**1.333**	**2.45**	**2.8**	**3.5**	**1.627**
Temp (°C)	**Analog Output Voltage (V)**							
25	4.012	-0.03	0.651	1.33	2.457	2.808	3.513	1.617
-25	4.01	-0.033	0.65	1.325	2.454	2.806	3.51	1.614
-50	4.016	-0.037	0.646	1.325	2.457	2.811	3.515	1.615
-100	4.014	-0.036	0.648	1.326	2.456	2.81	3.517	1.615
-150	4.011	-0.03	0.65	1.33	2.456	2.807	3.51	1.615
-170	4.014	-0.037	0.646	1.324	2.455	2.806	3.512	1.612
-180	4.015	-0.036	0.65	1.328	2.458	2.81	3.515	1.616
-190	4.007	-0.035	0.646	1.323	2.455	2.809	3.51	1.613
25	4.013	-0.04	0.645	1.327	2.457	2.811	3.515	1.617

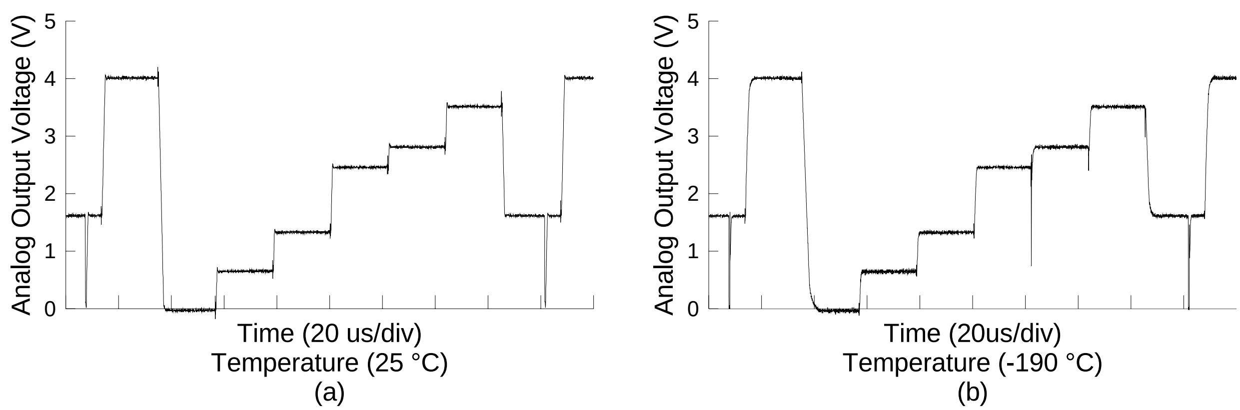

Figure 7. Output voltage waveforms for device 3 at 25°C and -190°C.

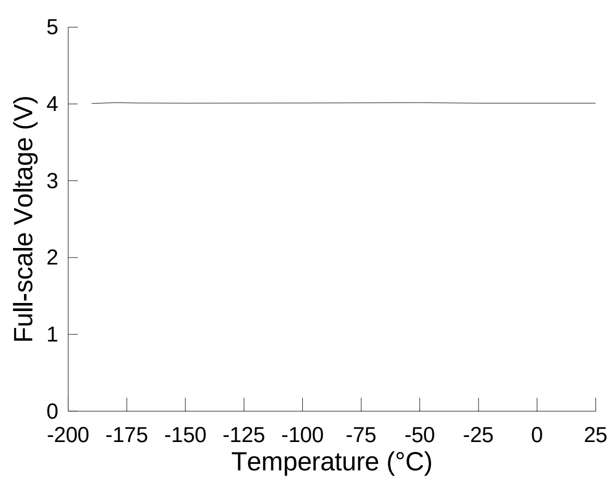

Figure 8. Device 3 full-scale voltage versus temperature.

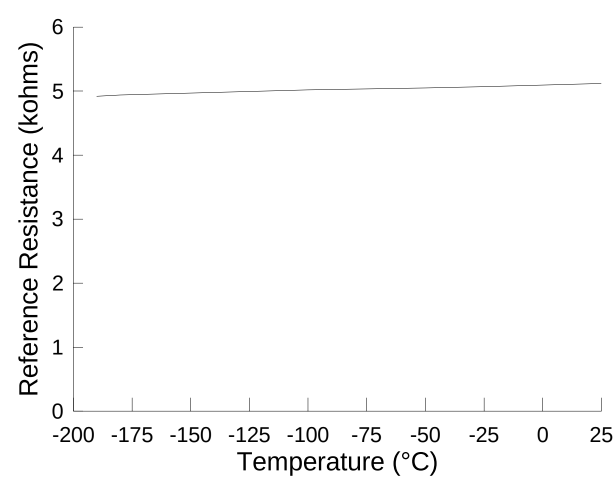

Figure 9. Device 3 reference resistance versus temperature.

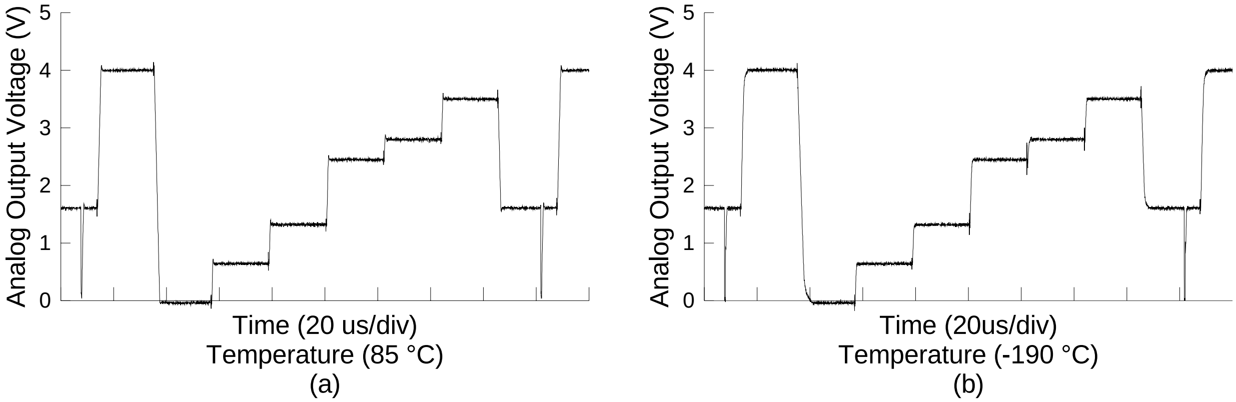

Figure 10. Pre-thermal cycling output voltage waveforms for device 1.

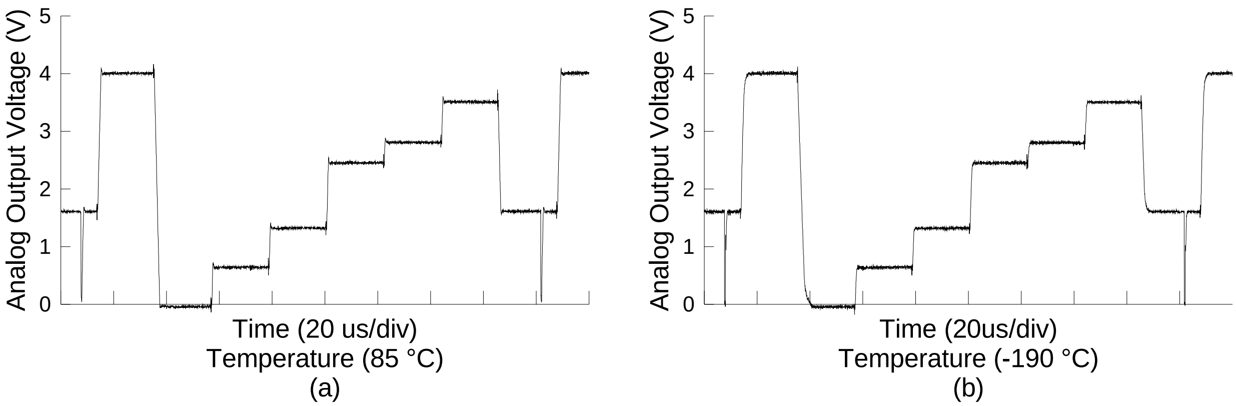

Figure 11. Output voltage waveforms for device 1after five thermal cycles.

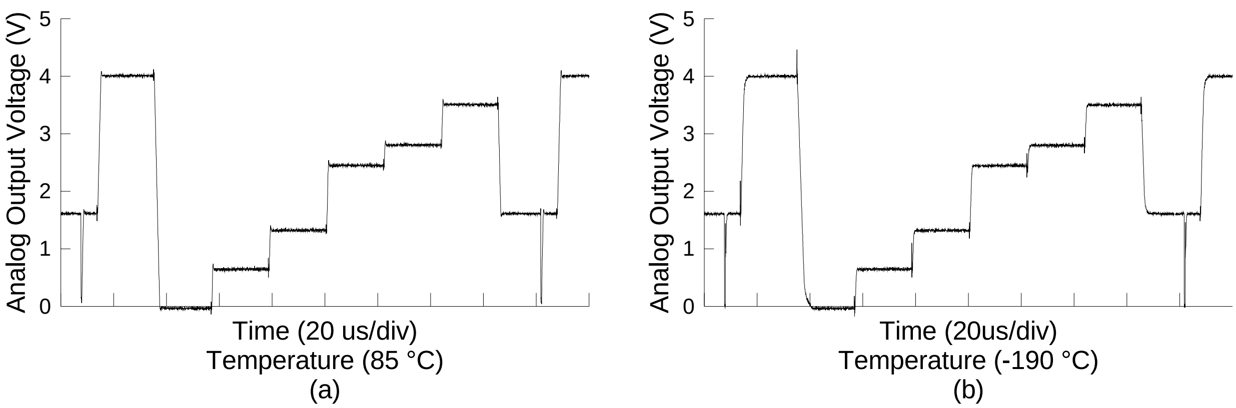

Figure 12. Output voltage waveforms for device 1 after ten thermal cycles.